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Monterey, California

FY 1974 NPS
INDEPENDENT DEVELOPMENT PROGRAM

by

ROBERT R. FOSSUM

July 1975

Summary Report for Period 1 July 1974-30 June 1975

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

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Thirteen summaries of exploratory development work carried out under a grant to the Naval Postgraduate School Research Foundation are included. This research was carried out in the areas of electrical engineering (slot lines; phase lock loops), aeronautics (aircraft survivability; composite materials for structures), material sciences (relation between high temperature compressive behavior and microstructure), mechanical engineering (fatigue life of ferrocement hull structures; flow fields), economics (hazardous employment

19. high temperature compressive behavior
fatigue life of ferrocement
periodic flow
missile allocation
combat dynamics
diffusion approximation
underwater acoustic parametric source

20. incentives for DoD personnel), operations research (missile allocation modeling; combat dynamics; shipboard tank designs), oceanography breakwater construction effects on ecology), and physics (evaluation of an underwater acoustic parametric source).

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FY 1974 NPS INDEPENDENT DEVELOPMENT PROGRAM

1. Introduction

The principal thrust of research and exploratory development program at the Naval Postgraduate School stems from its mission:

> To conduct and direct advanced education of commissioned officers, and to provide such other technical and professional instruction as may be prescribed to meet the needs of the Naval Service; and in support of the foregoing to foster and encourage a program of research in order to sustain academic excellence.

In fulfillment of the research and development program objectives and within the above constraints, the Naval Postgraduate School

> Initiates and conducts scientific and applied research (6.1) of a long-range nature in areas of special interest to the Navy.
>
> Conducts exploratory development (6.2) deriving from scientific program areas or in other areas specifically requested by the Navy.

In addition, NPS performs scientific research and exploratory development where uniquely qualified, for other agencies of the Department of Defense and, in defense related efforts, for other Federal Government agencies. NPS also furnishes consulting services for the Navy and, where specially qualified, for other agencies of the Department of Defense and in defense related efforts for other Government agencies.

This report summarizes the 1974 independent development program at the Naval Postgraduate School.

2. Background on the NPS Research Program

The Navy has developed the Naval Postgraduate School as an academic instiution which uses traditional university educational methods to address the special graduate education requirements of the Navy. The Superintendent of the Naval Postgraduate School is a Rear Admiral of the line of the Navy. He is supported by a dual management structure, part military and part civilian. The faculty, mostly civilian, is responsible for the academic programs and, in support of these, conducts an active supporting research effort. The

The military staff specifies the educational needs of the Navy, in terms of curricula, and provides administrative logistic support.

At the Naval Postgraduate School, as in other academic institutions, the faculty is organized into departments. The department represents a resource center of faculty members with allied disciplinary specialization. Currently, the departments at the Naval Postgraduate School include Aeronautics, Electrical Engineering, Government, Mathematics, Mechanical Engineering, Meteorology, Oceanography, Operations Research and Administrative Sciences, and Physics and Chemistry. Inter-disciplinary groups which have effective departmental status include Computer Science, Engineering Acoustics, and Anti-Submarine Warfare.

Research and development projects are largely conducted by the individual faculty members on a project basis. Projects typically originate from proposals prepared either by individual faculty members, or by groups of faculty members from the same or different departments. From an administrative viewpoint, the research program at NPS is composed of two parts, the NPS Foundation Program and the Sponsored Research Program. The Research Foundation Program, which is funded by grants from the Chief of Naval Research (for 6.1 independent research funds) and the Director of Navy Laboratories (for 6.2 independent development funds), is administered internally by a Research Council, made up of faculty members appointed by the Provost. The Dean of Research is the Chairman of the Council. The Council meets periodically to review faculty proposals, allocate funding and review results of completed projects. The required outline of these proposals is shown in Appendix I.

3. Projects

During FY 1974, thirteen projects were supported under the Foundation independent development program. These included projects in the three general areas of Applied Science, Engineering, and Operations Research/Administrative Science. Status reports on these projects follow.

1. Slot Line Investigations

Investigator: Asst. Prof. Jeffrey B. Knorr, Electrical Engineering

Support: Foundation Research Program (6.2)

Objective: The objective of this program is to continue theoretical and experimental studies involving slot transmission line. These investigations were begun with Foundation support during FY 73. Work remains in the following areas: 1) Broadband microstrip transition; 2) Slot line isolator (experiment); 3) Discontinuities (other than end effect); 4) Coupled slots; 5) Slot antennas.

Summary: Frequency dependent solutions for the wavelength and characteristic impedance of microstrip, slotline and coplanar strips on dielectric substrate have been obtained. Both single and coupled slots and microstrips have been treated. Accurate and efficient computer programs have been developed. A perturbational solution for the phase constant of a slot or microstrip transmission line on ferrite substrate has been obtained. Various types of circuits and discontinuities have been analyzed including resonant slots, slot-microstrip transitions, slot line and effect, end coupled slots and surface metal adhesive effects.

Publications: J. B. Knorr, "Slot Line Transitions," IEEE Trans. Microwave Theory Tech., vol. MTT-22, pp. 548--554, May 1974.

J. B. Knorr, K.-D. Kuchler and A. Tufekcioglu, "Hybrid Mode Analysis of Planar Transmission Line Structures," Paper presented at 8th Annual Asilomar Conference on Circuits, Systems, and Computers (December 1974) and published in Conference Proceedings.

K.-D. Kuchler and J. B. Knorr, "Coupler Design Using Dispersive Transmission Lines," Paper presented at 8th Annual Asilomar Conference on Circuits, Systems, and Computers (December 1974) and published in Conference Proceedings.

J. B. Knorr and K.-D Kuchler, "Analysis of Coupled Slots and Coplanar Strips on Dielectric Substrate," IEEE Trans. Microwave Theory and Techniques, to be published July 1975.

Asst. Prof. Jeffrey B. Knorr, Elec. Engineering (cont.)

Publications:	J. B. Knorr and A. Tufekcioglu, "Spectral Domain Analysis of Microstrip Characteristic Impedance," *IEEE Trans. Microwave Theory Tech.*, to be published.
Theses:	A. Tufekcioglu, "Hybrid Mode Analysis of Microstrip on Dielectric or Ferrite Substrate," Electrical Engineer Thesis, Naval Postgraduate School, Monterey, CA., September 1974.

2. Studies of Phase-Locked Loops

Investigator: Assoc. Professor John E. Ohlson, Electrical Engineering

Support: Foundation Research Program (6.2)

Objective: The objective is to model the carrier amplitude as the sum of a constant amplitude plus a randomly-varying factor, and set up the Fokker-Planck equation to obtain the stationary probability density of the phase error. The problem of cycle-slipping can then be considered by taking the Fokker-Planck equation and deriving from it the average time-to-slip.

Summary: In some applications of acquiring a sinusoid in noise, the frequency can be assumed to be known. The causal maximum a posteriori (MAP) estimates of phase and amplitude are well-known but are inconvenient to use for oscillator synchronization in real systems. Hence a phase-locked loop (PLL) is generally used, but the loop bandwidth is usually chosen in an *ad hoc* fashion. We show that the casual MAP estimator can be implemented *exactly* as a first order PLL whose loop gain is a function of the synchronously detected envelope of the signal-using the phase estimate as the reference for detection. Furthermore, it was demonstrated that if an automatic gain control capability precedes the PLL and synchronous detector that the loop gain is automatically varied in the optimum fashion. Finally, the estimator is easy to implement in practice. The phase error probability density of the first-order phase locked loop was determined when the signal amplitude has a wideband noise component. The problem was solved using the Fokker-Planck equation. Use is made of the "correction term" for conversion from ordinary calculus to the Ito calculus model. For comparison, an examination is made of the wrong answer which is obtained if the correction term is not used. Serious errors in previously published work were pointed out.

Publications: J. E. Ohlson, "On Optimal Phase Acquisition," *1974 IEEE Symposium on Information Theory*, Notre Dame, Indiana, October 1974.

J. E. Ohlson, "Statistics of the First Order Phase-Locked Loop with Fluctuating Signal Amplitude," submitted to *IEEE Aerospace and Electronic Systems Transactions.*

3. Aircraft Survivability and Vulnerability

Investigator: Asst. Prof. H. L. Power, Aeronautics

Support: Foundation Research Program (6.2)

Objective: This research will provide a better understanding of the events leading to the damage or destruction of liquid filled tanks when penetrated by high velocity projectiles. To date the complex mechanisms producing failure are not fully understood and as a result a survivable tank design is not available. The proposed research will experimentally study the initial projectile-wall interaction and the resulting strong shock which propagates into the tank fluid. An approximate theory is available for this so-called shock phase of the hydraulic ram problems but experimental verification has not been accomplished to date. It is proposed that the experiments of this research be correlated to substantiate this work and to provide information as to its deficiencies.

Summary: The theoretical predictions were compared to a series of experiments in which projectile shape, impact velocity, and mass were varied. Impact and exit velocities were measured using chronograph screens and high speed counters. The tank entry wall was simulated by an 7075-T6 Aluminum plate of thickness .05, .09, or .16 inches. Three projectile nose shapes ranging from hemispherical to a 1.6 fineness ratio ogive were tested. The .222 caliber projectiles did not tumble before impacting normal to the tank wall. Spark shadowgraphs of these copper-jacketed lead projectiles just after penetration showed that no appreciable deformation of the projectile shape occurs during the penetration. The resulting damage size was approximately equal to the projectile maximum cross sectional area.

Publications: Paper entitled "Projectile Energy Loss During the Penetration Phase of Hydraulic Ram", by Prof. H. L. Power; submitted to the Journal of Aircraft.

Thesis: HYDRAULIC RAM SHOCK PHASE EFFECTS ON FUEL CELL SURVIVABILITY, by LT L.G.Happel, March 1974

4. Composite Materials for Aircraft Structural Applications

Investigator: Assistant Professor M. H. Bank, Aeronautics

Support: Foundation Research Program (6.2)

Objective: Objectives and General Plan of Attack. The initial objective of this program is to investigate techniques of fabrication of high quality hybrid laminates, and to investigate the effects on material properties of changes in reinforcement ratios and geometric orientations. Initial studies will utilize compatible prepreg systems of graphite/epoxy and glass-epoxy materials. After testing, the scanning electron microscope will be used to examine the resulting fracture surfaces. Stress-strain diagrams will be plotted and an attempt made to relate "toughness" as indicated by area under the curve to fiber orientation. Later studies will include an attempt to relate toughness to low-energy impact resistance. The initial effort will be establishment of adequate research facilities.

Summary: The major effort during this period was the establishment of an Advanced Composite Materials Laboratory. This facility is capable of producing high-quality specimens of glass-epoxy , and hybrid advanced composite materials for experimental studies. The laboratory facilities include a 0°F. storage box, hydraulic presses with heated platens, a thermal control and recording system, a vacuum-bagging system, curing oven, lay-up table, and cut-off wheel. There was no experimental research or thesis work in this area at the Naval Postgraduate School prior to this time. The follow on program will commence the investigations above and mentioned below.

Publications: David M. Saba, "A Photoelastic Investigation of Effects of Hole Size on Stress Concentrations in Advance Composite Materials," June 1975 (underway).

Clark M. Bruce, "A Moire' Fringe Investigation of the Stress Field around a Hole in an Advanced Composite Plate," September 1975 (underway)

James M. Gill, "Graphite Film/Graphite Fiber Hybrid Composite Materials," September 1975 (underway).

Carlos Alves, "Edge Effects on Stress Concentrations in Fiberglass-Reinforced Composite Materials," September 1975 (underway).

5. The Relationship Between High-Temperature Compressive Behavior and Microstructure for Selected Metallic Systems

Investigator: Assistant Professor Glen Edwards, Mechanical Engineering

Support: Foundation Research Program (6.2)

Objective: This study is to correlate several microstructural features of certain metals with corresponding compressive creep behavior. A specific objective is to investigate the effects of grain size and shapes on creep behavior of aluminum containing Al_2O_3 dispersoids. This is a continuing project.

Summary: An experimental attempt was made to produce by thermomechanical processing unique microstructures in aluminum containing 4 volume percent Al_2O_3 particles. A concurrent effort was made to develop a theoretical model explaining the creep behavior of zinc-based alloys containing dispersed particles of Al_2O_3 and tungsten. Although the Al-Al_2O_3 study proved too difficult for the available equipment, the theoretical analysis or previously unexplained creep data on zinc-based alloys was quite successful. A particle source theory was developed which explained the unusually high stress dependence of strain rate observed. Since unusually large stress exponents are characteristic of dispersion-strengthened alloys, this theoretical model may be partially applicable to other material systems. The following publications have resulted. An experimental study of texture strengthening in titanium at elevated temperatures proved that at least a 50% strength increase at temperatures of 700°K can be realized by the deliberate introduction of preferred orientation. Anisotropic creep behavior in α-titanium was associated with the anisotropy in elastic modulus. An analysis of existing data concerning the high-temperature texture strengthening of zinc yielded results similar to those obtained for α-titanium.

Publications: G. R. Edwards, "A Plausible Explanation for Unused Mechanical Effects in Zinc-Based Particulate Composites," Abstracts, ASM Materials Science Symposium, Detroit, 1974.

G. R. Edwards, T. R. McNelley and O.D. Sherby, "Diffusion-Controlled Deformation of Particulate Composites," Submitted to Philosophical Magazine, 1975.

Assistant Professor Glen Edwards, Mechanical Engineering

Publications:

ENS. R. W. Rolfes, "High-Temperature Texture Strengthening in α-Titanium," MS Thesis, June 1974, Naval Post-Graduate School, G. R. Edwards, advisor.

G. R. Edwards, T. R. McNelley, and O. D. Sherby, "High-Temperature Texture Strengthening in Zinc," Scripta Metallurgica, 1974, vol. 8, pp 475-480.

G. R. Edwards and R. W. Rolfes, "High-Temperature Texture Strengthening in α-Titanium" to be submitted. Scripta Metallurgica, May 1975.

6. Factors Affecting the Fatigue Life of Ferrocement

Investigator: Assistant Professor Edwin A. McKinnon, Mechanical Engineering

Support: Foundation Research Program (6.2)

Objective: The objective of this study is to investigate the fatigue behavior of ferrocement. The cyclic dependence of the monotonic stress-strain properties will be investigated. Recent work has shown that the modulus of elasticity of ferrocement is cyclic dependent. Additional work will be done to investigate this phenomenon and the cylic dependency of flexural, impact, and tensile strengths. Other areas of interest are the influence of wire orientation, speciman thickness, wire volume fraction, environment, cement-sand ratio, cement-water ratio, and the concentration of a $Cr0_3$ additive on the fatigue life of ferrocement.

Summary: The key material parameters of ferrocement construction are the following: type of wire used, mortar, sand, quantity of water, additives to the water (if any), wire orientation, number of layers of wire, thickness of specimen, and method of curing. During this phase of the study, the following parameters were kept constant: water additives, wire orientation, number of layers of wire, and specimen thickness. Two types of wire were used: galvanized and ungalvanized. Ferrocement made using ungalvanized wire has superior fatigue properties. Some specimens were water cured and others were steam cured. Those specimens which received a water cure had longer fatigue lives. There were two variations of mortar tested. One specimen used Portland cement type V with carefully screened and graded beach sand. The other used Kaiser CHEMCOMP cement and quarry sand. Specimens fabricated using the mortar made from Portland cement tended to give longer fatigue lives than those made from Kaiser CHEMCOMP. Three water/cement ratios were considered: 0.35, 0.40, and 0.45. As the quantity of water used is decreased, the fatigue strength of ferrocement is increased. The practical limit from the point of view of workability during fabrication is from 0.35-0.40, amd 0.45. As the quantity of water used is decreased, the fatigue strength of ferrocment is increased. The practical limit from the point of view of workability during fabrication is from 0.35-0.40, depending upon the type of sand used. Tests to investigate the cyclic dependency of the fluxural and tensile strengths of ferrocment were carried out on several groups of specimens. Regardless of composition, the basic

Assistant Professor Edwin W. McKinnon, Mechanical Engineering

Summary:	conclusion was the same. The flexural and tensile properties of ferrocement decrease as the material is subjected to cyclic loading. Reductions in strength of up to 20% are not uncommon. This finding is of particular importance to marine architects. As a ship made from ferrocement is subjected to cyclic loading, the flexural strength decreases in a fairly linear manner and the tensile strength drops about 20% during the first quarter of the fatigue life and then stays fairly constant until immediately before failure.
Publications:	Thesis, Simpson, M. G., Fatigue of Ferro-Cement, Thesis for the Degree of Master of Science and for the Degree of Mechanical Engineer, Naval Postgraduate School, June 1974.
	Papers: E. A. McKinnon and M. G. Simpson, Fatigue of Ferro-Cement accepted for publication by the Journal of Testing and Evaluation of ASTM.
	M. G. Simpson and E. A. McKinnon, The Influence of Water-to-Cement Ratio on the Fatigue of Ferrocement, submitted for publication to Naval Research Reviews.

7. Periodic Flow about Bluff Bodies

Investigator: Professor T. Sarpkaya, Mechanical Engineering

Support: Foundation Research Program (6.2)

Objective: The research proposed herein concerns the measurement and theoretical prediction of the forces acting on a circular cylinder, flat plate, sphere, and a disk immersed in a periodic flow characterized by $V = V_1 \sin 2\pi f_1 t$. The range of the parameters will be: $10^3 < V_1 D/\nu < 3 \times 10^5$ and $0.1 < f_1 D/V_1 < 0.3$. Experiments will be conducted in the existing, U-shaped, periodic flow channel. Potential flow methods based on discrete Rankine vortices, Fourier analysis, and other methods described in the proposal will be used to analyze the data and to predict the behavior of the flow. Overall, the investigation will seek to increase, through analysis and experimentation, the scope of the existing information and the understanding of time-dependent flow about smooth as well as rough bluff bodies.

Summary: The in-line and transverse forces acting on circular cylinders and the in-line force acting on spheres immersed in a harmonically oscillating fluid in a U-shaped vertical tunnel have been measured. The drag, inertia and the transverse force (lift) coefficients have been determined through the use of a Fourier analysis and found to depend on a period parameter. The results have shown that the transverse force on cylinders is as large as the in-line force and alternates at frequencies ranging from one to five times the driving frequency of the fluid within the range of subcritical Reynolds numbers encountered in the investigation.

Publications: Sarpkaya, T., "Forces on Cylinders and Spheres in a Sinusoidally Oscillating Fluid," Journal of Applied Mechanics of ASME, Vol. 42, March 1975, pp. 32-37.

Sarpkaya, T., "Wave Forces and Periodic Flow About Cylinders," Proceedings of the 14th International Conference on Coastal Engineering Copenhagen, Vol. 1, June 1974, pp. 271-274.

Tuter, O., "Periodic Flow About Cylinders," M.S. Thesis, Dec. 1974, Naval Postgraduate School, Monterey, CA.

Jones, Keith, H., "Forces on Cylinders near a Plane Wall in Periodic Flow," M.S. Thesis, June 1975, Naval Postgraduate School, Monterey, CA.

8. The Economics of Hazardous Employments

Investigator: Assoc. Prof. Michael K. Block, Operations Research

Support: Foundation Research Program (6.2)

Objective: Within the Department of Defense many hazardous civilian occupations exist, e.g., fireman, etc. The objective of this research is to model individual employment decisions in situations where at least one of the occupational and/or work choices involves a relatively important non-monetary hazard. Emphasis will be placed on the relationship between the hazards of a particular occupation and the monetary compensation required by the individual in order to undertake the occupation or task. Specific attention will be directed here towards deriving relationships between changes in the probability of bodily harm and changes in the compensation required to induce the individual to choose the occupation or task.

Summary: In formulating a model with which to explore the relationship between changes in the possibility of bodily harm and changes in the compensation required to induce the individual to accept the increased hazard, it became apparent that this required a contribution in basic utility theory. The first step in this process was to assume that there existed, for some individuals, a monetary equivalent to all nonmonetary hazards. Thus, it was shown that for such individuals the traditional assumption of risk aversion implied that as the probability of the hazard increased the marginal or increased payment decreased. For example it was shown, in theory at least, that to keep the volunteer rate constant a 10% increase in the probability of bodily harm would require less than a 10% increase in hazardous duty pay if potential volunteers had monetary equivalents to bodily harm. Next in this basic extension of utility theory it was necessary to explore the logical conditions under which a monetary equivalent to bodily harm would exist. A set of sufficient conditions for the existence of a wealth equivalent to nonmonetary or non-market hazards has been postulated and research is continuing in this area. At this time it has been tentatively established that to assume that a wealth equivalent to death does not exist one must assume that the incremental or marginal evaluation of wealth must be greater in death than in life or that an individual has a preference for risk.

Associate Professor Michael K. Block, Operations Research

Publications:

Eealth Equivalents, Risk Aversion, and the Marginal Benefit from Increased Safety (with R. C. Lind), NPS Technical Report, 55Xb74051, May 1974.

Paper of "Wealth Equivalents", to be presented at the International Meeting of the Institute of Management Sciences, Kyoto, Japan, 1975.

"Approaching the Value of Human Life," paper in preparation.

9. Missile Allocation Models

Investigator: Associate Professor G. T. Howard, Operations Research

Support: Foundation Research Program (6.2)

Objective: A good deal of literature is available on both offensive and defensive missile allocation problems, but several areas remain essentially untreated. Among these is the problem of determining the optimal allocations of offensive and defensive missiles when the two sides have differing estimates of the relevant parameters in the problem. For example, the targets may be assigned different values by the opposing sides. Likewise, one or both of the opponents may improperly assess the single shot kill probabilities for the attacking weapons $\hat{p}$ or for the interceptors p. In the face of uncertainty about the system parameters, it is important to develop "robust" strategies which perform well under a variety of conditions. The object of this research was to examine offensive and defensive missile allocations in which the defenders at a target are assumed to be depleted on a one for one basis with the incoming offensive missiles. These models usually assume that the defensive missiles have a single shot kill probability of one.

Summary: In this project the problem of determining optimal offensive and defensive strategics for a collection of point targets was addressed under the assumption that the defense first places his defenders around his point targets and then, after viewing this placement, the offense allocates his missile to the targets. Both offensive and defensive missiles were assumed to be imperfect. Some effort was also devoted to extending a model previously developed by G. Howard and K. Shumate, entitled "A Proportional Defense Model," Naval Research Logistics Quarterly, March 1974. The purpose was to examine the variations in missile deployment which result from differences in target valuation by the offense and defense. In particular, the object was to determine how the offense might exploit these differences.

Publications: Thesis by B. Supachart, "Missile Allocation Models for the Attack of Defended Targets," September 1974.

10. Optimization of Combat Dynamics

Investigator: Assoc. Prof. James G. Taylor, Operations Research

Support: Foundation Research Program (6.2)

Objective: The objective of the proposed research is to examine the structure of optimal allocation policies for tactical situations describably by Lanchester-type equations of warfare. By considering idealized (yet appropriate) dynamic models, insight will be gained into such questions as: (a) How should targets be selected? (b) Do target priorities change over time? (c) How does the number of target types affect the selection? (d) Do conflict termination circumstances affect the optimal allocation policies? (e) How is target selection affected by the nature of the attrition process? (f) What is the effect of ammunition constraints? (g) How does the uncertainty and confusion of combat affect the optimal selection rules?

Specific objectives are the identification of decision parameters and development of general principles for target selection, regulation of firing rate, allocation of military resources in dynamic combat situations. Additionally, this research is being pursued with an eye to making additions to the literature of generalized control theory (deterministic optimal control/differential games) whenever appropriate.

Summary: This has been a continuing project. Previous work had identified several gaps in our knowledge about the implications for tactical decision making of various functional forms for the mutual attrition of two homogeneous forces in Lanchester-type combat. Consequently, several investigations were undertaken to develop a better understanding of the dynamics of combat between two homogeneous forces described by deterministic Lanchester-type equations. The Riccati equation satisfied by the force ratio was examined to provide qualitative insights into the dynamics of combat. "Instantaneous" linear and square laws which are "local" conditions for winning were shown to apply for Lanchester-type formulations with time-varying system effectivenesses. "Global" conditions for winning were also developed. By additionally considering the instantaneous loss ratio, insight was gained into the consequences of concertration of forces in aimed-fire combat between two homogeneous forces with superimposed effects of supporting fires (which are not subject to attrition).

Associate Professor James G. Taylor, Operations Research

A mathematical theory was developed for solving deterministic Lanchester-type "square-law" attrition equations for combat between two homogeneous forces with temporal variations in fire effectivenesses (as expressed by the Lanchester attrition-rate coefficients). A general form was given for expressing the solution of such variable-coefficient combat attrition equations in terms of Lanchester Functions which were introduced and can be readily tabulated. Different Lanchester Functions arise from different mathenatical forms for the attrition-rate coefficients. Results were given for two such forms. Additionally, some work was done on characterization of optimal strategies (i.e., necessary conditions of optimality) for certain differential games of interest (as pertains to time-sequential tactical allocation).

Publications:

Paper by J. Taylor and S. Parry, "Force-Ratio Considerations for Some Lanchester-Type Models of Warfare," Opns. Res., to appear (Vol. 23, No. 4, 1975).

J. Taylor, and G. Brown, "Canonical Methods in the Solution of Variable-Coefficient Lanchester-Type Equations of Modern Warfare," Opns. Res., to appear.

J. Taylor, "Necessary Conditions of Optimality for a Class of Differential Games with Bounded State Variables," submitted to IEEE Trans. on Automatic Control.

Report by J. Taylor and G. Brown, "A Mathematical Theory for Variable-Coefficient Lanchester-Type Equations of 'Modern Warfare'," Tech. Report NPS55TW74111, Naval Postgraduate School, Monterey, CA, November 1974.

Related Thesis Directed:

C. Macciaroli, "A Review of Literature on the Theory of Visual Target Detection Probabilities," M.S. Thesis in Operations Research, Sept. 1973.

D. Holdsworth, "The Force-Oriented Defense: An Expected-Value Approach," M.S. Thesis in Operations Research, September 1973.

M. Chase, "A Lanchester-Type Model with Logistics Considerations," M.S. Thesis in Operations Research, September 1973.

Associate Professor James G. Taylor, Operations Research

Publications:

B. Barr, "Techniques for Including Suppressive Effects in Lanchester-Type Combat Models," M.S. Thesis in Operations Research, March 1974.

J. Ellis, "A Problem of Allocation of Supporting Fire in Combat as a Zero-Sum Differential Game," M.S. Thesis in Operations Research, March 1974.

D. Hale, "The Selection of Measures of Effectiveness for Small Arms Experiments," M.D. Thesis in Operations Research, March 1974.

M. Mulhern, "Ordering in a Sequential Storage System," M.S. Thesis in Operations Research, March 1974.

M. Selvitelle, "Concerning Visual Detection of Moving Personnel Targets," M.S. Thesis in Operations Research, March 1974.

11. Diffusion Approximation Methods with Application to Shipboard Holding Tank Design

Investigator: Asst. Prof. M. U. Thomas, Operations Research

Support: Foundation Research Program (6.2)

Objective: General Problem and Related Work: The problem of interest concerns a storage facility (tank) in which the level, $X(t)$, at a point in time t varies due to inputs and outputs either or both of which may be random. The facility is of limited capacity, therefore whenever $x(t)$ exceeds some level of k there will be overflow. On the other hand, whenever storage is depleted, i.e. $X(t) = 0$, the processor system that effects output becomes idle. It is of interest to gain an understanding of the stochastic behavior of the storage level $X(t)$ for given conditions on the inputs and output processes. In particular, some issues that are most pertinent to the design and evaluation of such storage facilities are the lengths of time until overflow and storage depletion occurs, the amount of overflow, and the duration of overflow and idle periods for given input and output processes.

Summary: Two models based on diffusion processes are presented for describing $[x(t): t \geq 0]$. The first model consists of representing $x(t)$ by an Ornstein-Uhlenbeck process with an absorbing barrier corresponding to K, the limited capacity system threshold. An accurate method for estimating the first two moments of the time required to reach this barrier has been derived that is simple and computationally feasible. While these results have wide applicability, a review of the data collected by NAVSEA on sewage generation rates suggests that other models might be more suitable. The second model attempts to generalize by including a type of nonhomogeneity in the process of generating and, hence, processing the sewage. In particular, using results from Renewal Theory $[x(t): t \geq 0]$ consists of alternating diffusion processes with appropriate barriers. One of these diffusion processes has a high instantaneous mean while the other has a low, or possibly zero, mean corresponding to day and night flows, or any periods where it is reasonable to assume that the rates alternate between two constant values. This model allows one to examine directly the length of time to overflow, or capacity, and the idle periods. Moreover, it can easily be extended to allow for a combination of more than than

Summary:	two diffusion processes. The major value and, hence, the motivation for developing these models is in systems design. Here one must specify components according to, among other things, tank size and processing rates. Given a sufficient description of the flows, one can then formulate and solve this as a decision analysis problem.
Publications:	Thomas, M. U., "Some mean first passage time approximations for the Ornstein-Uhlenbeck Process," Journal of Applied Probability, September 1975.

12. Sublittoral Ecology off Del Monte Beach in Relation to Possible Breakwater Construction

Investigator: Prof. E. C. Haderlie, Oceanography

Support: Foundation Research Program (6.2)

Objective: The object of this project is to complete the ecological survey began in 1971. During FY 74 it is proposed to make two additional cruises on R/V ACANIA to sample each station on all ecological transects once more and to profile the bottom topography along each transect. Several more Scuba dives will be made to recheck the ecological grids permanently established off Del Monte Beach. The main effort during FY 74 was devoted to analyzing the data and identifying the organisms in the extensive collections. If and when the breakwater complex is built, extensive data on the ecological conditions in the area prior to construction will have been published.

Summary: This project was designed to collect ecological information on a shallow water marine environment before major construction of a breakwater complex altered the environment. Eight cruises of the R/V ACANIA and over 200 SCUBA dives have collected extensive information on the nature and thickness of bottom sediments, rock outcrops, benthic animals and plants, and rock boring animals of the shale outcrops. We now have a fairly adequate amount of base line biological and oceanographic data from the shallow water off Del Monte Beach to be able to assess ecological changes that may occur when a new breakwater-harbor complex is built.

Publications: Haderlie, E.C., J. C. Mellor, C. S. Minter, III, & G. C. Booth. 1974 The Sublittoral Benthic Fauna and Flora off Del Monte Beach, Monterey, California. The Veliger 17(2): 185-204.

13. Development and Evaluation of an Underwater Acoustic Parametric Source

Investigator: Professor Anthony I. Eller, Physics & Chemistry

Support: Foundation Research Program (6.2)

Objective: The objectives of the proposed research are 1) to assemble a nonlinear acoustic parametric source similar to one that was developed at the Naval Research Laboratory by NPS personnel, 2) to evaluate the use of the parametric source as a research tool in indoor tank experiments at NPS, and 3) to test performance of the source in the ocean.

Summary: An acoustic parametric source was assembled and tested. The results are described in the NRL report below. The experimental results were also presented at a meeting of the Acoustical Society of America as a paper, performance of an acoustic parametric.

Publications: A. I. Eller, Adaptation of the NRL Acoustic Research Tank Facility for Experiments in Parametric Sonar, with Preliminary Results, Naval Research Laboratory Report No. 7513, January 1974.

A. I. Eller and R. C. Khosla "Surface Reflection of an Underwater Acoustic Parametric Source," Journal of Accoustical Society of America, Vol 55 (S-23a) 1974.

OUTLINE TO BE USED IN FOUNDATION RESEARCH PROPOSALS

NAVAL POSTGRADUATE SCHOOL
Monterey, California

From: Date:
To: Research Council For FY 19__
Via: (Appropriate Department Chairman)

Subj: Proposal to include a research project in the Foundation Research Program

PROJECT TITLE

Part I Technical Proposal

1. Background

   a. General tutorial background on the problem area.

   b. Relevance to a Department of Defense research area.

   c. Related work by others in the field, including references.

   d. Opportunities for student thesis involvement.

2. Program Description

   a. Objectives.

   b. General plan of attack.

   c. Description of experimental setup.

   d. Facilities available.

   e. Additional facilities required.

   f. Expected output in terms of technical reports, papers, etc.

   g. Travel plans and purposes.

3. Research background of investigator:

   a. All Foundation support provided during the previous five fiscal years, to include Project title and all publications resulting therefrom, related theses directed, etc.

   b. Background and research experience of investigator, including list of significant publications related to the proposed investigation.

Part II Administrative Proposal

1. Estimated cost of project for this academic year
   - a. Salary of investigator during research period.
   - b. Support personnel: List salary cost, including benefits and earned leave.
   - c. Capital equipment: Name and identification for each major item of capital equipment to be purchased.
   - d. Supplies.
   - e. Special services:
     - (1) Computer time and type of computer support required.
     - (2) Itemize and estimate cost of other services not included elsewhere.
     - (3) Travel costs.
   - f. Total cost.

2. Schedule
   - a. Estimate duration of the proposed project.
   - b. Stipulate the period during which you desire to be relieved of teaching to work on your Foundation Research project. Only faculty members in their first year at NPS may request support during their intersessional.
   - c. Support personnel: State man-months and category (technician, programmer, etc.) of support personnel requirements. Specify how you anticipate the required personnel can be made available.
   - d. Describe briefly any other sponsored work on which you expect to be active during this academic year, its relation to the present Foundation proposal (if any), and when the work will be done.

3. Plans for determining sponsored research in this area
   - a. What chances are there for sponsorship of this project through other sources of funding?
   - b. What efforts have been made to locate sponsorship?

4. RDT&E category

Do you consider this project to be in Category 6.1 Research, Category 6.2 Exploratory Development?

Part III Appended documents

Papers, reports, etc., to be considered in support of this proposal.

Research. Includes scientific study and experimentation directed toward increasing knowledge and understanding in those fields of the physical, engineering, environmental, biological-medical, and behavioral-social sciences related to long-term national security needs. It provides fundamental knowledge for the solution of identified military problems. It also provides part of the base for subsequent exploratory and advanced developments in Defense-related technologies and of new or improved military functional capabilities in areas such as communications, detection, tracking, surveillance, propulsion, mobility, guidance and control, navigation, energy conversion, materials and structures, and personnel support.

Exploratory Development. Includes all effort directed toward the solution of specific military problems, short of major development projects. This type of effort may vary from fairly fundamental applied research to quite sophisticated breadboard hardware, study, programming and planning efforts. The dominant characteristic of this category of effort is that it be pointed toward specific military problem areas with a view toward developing and evaluating the feasibility and practicability of proposed solutions and determining their parameters.

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